D meson enhancement in pp collisions at the LHC due to nonlinear gluon evolution

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The parton distribution functions, PDFs, of the free proton are determined through global fits obtained using the linearly-evolved DGLAP equations. However, when the small-x and small-Q^2 region is included in the DGLAP fits, they are not as good. At low Q^2, the small-x gluon density increases and gluon fusion may become significant, generating nonlinearities in the evolution equations. When these nonlinearities dominate, in the gluon saturation region, DGLAP fails.

Outside the saturation region, incorporating the non-linearities was shown to improve the leading order (LO) global fits in the small-x and Q^2 regions [1]. The nonlinearly-evolved gluon distributions at $Q^2 \lesssim 10$ GeV^2 and $x \lesssim 0.01$, are enhanced relative to linear evolution. In Ref. [2], charm production in pp collisions at the LHC was shown to be sensitive to this gluon enhancement and the resulting charm enhancement was quantified.

The enhancement increases as x and Q^2 decrease. Consequently, the maximum enhancement will be at $\sqrt{s} = 14$ TeV and small charm quark transverse momentum. The sensitivity of the charm enhancement to the value of the charm quark mass, m_c, as well as to the choice of the factorization, Q_F^2, and renormalization, Q_R^2, scales was studied in Ref. [2]. The most significant charm enhancement is when m_c and Q^2/m_T^2 are both small. The largest enhancement, about a factor of 5 at central rapidities, is obtained with $m_c = 1.3$ GeV and $Q^2 = m_T^2$. However, in Ref. [2], the enhancement was described only for charm production. Neither its subsequent hadronization to D mesons nor its decay and detection were considered. Here, we address these issues to determine whether the charm enhancement survives hadronization and decay to be measured in the ALICE detector [3].

We first consider how much of the LO charm enhancement survives in the final state D meson distributions. We show that, for the most optimistic case, the D enhancement is a factor of three for $p_T^D \rightarrow 0$.

Since the ALICE detector can reconstruct $D^0 \rightarrow K^- \pi^+$, we determine whether the surviving D enhancement can be detected above the expected experimental statistical and systematic uncertainties. To determine realistic statistical uncertainties, we make an NLO calculation compatible with our LO result [3]. We assume that the enhancement calculated at LO is the same when calculated at NLO. Then we demonstrate that detection of the enhancement is possible.

Finally, we consider whether NLO charm cross sections, calculated with linearly-evolved PDFs and differ-
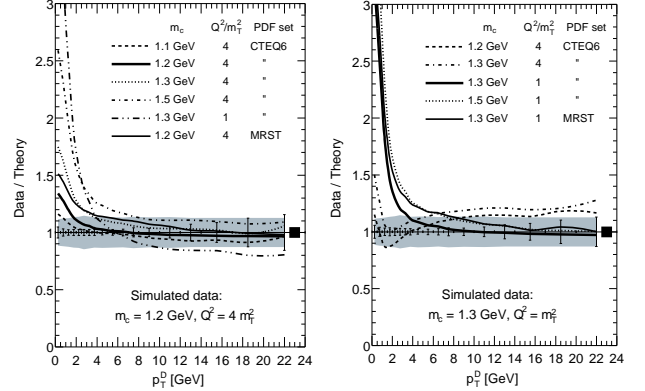

FIG. 1: Ratio of the generated ALICE data relative to NLO calculations. The left-hand side shows the result for $m_c = 1.2$ GeV and $Q^2 = 4m_T^2$ while the right-hand side is the result for $m_c = 1.3$ GeV and $Q^2 = m_T^2$.

ent combinations of m_c, Q_F^2 and Q_R^2, can mimic the charm enhancement. Our results show that this is unlikely. We consider the ratio of the simulated data, including the enhancement, to calculations using a range of m_c and Q^2 along with PYTHIA string fragmentation, denoted "Data/Theory". We then try to reproduce this result with NLO calculations employing linearly-evolved PDFs and tuning m_c and Q^2. If no set of parameters can describe both the high- (unenhanced) and low- (enhanced) p_T^D components of the distribution equally well, and, if the set that best reproduces the high-p_T^D part underestimates the low-p_T^D part, there is a strong indication of nonlinear effects.

The Data/Theory plots are shown in Fig. 1. The points with the statistical (vertical bars) and p_T-dependent systematic (shaded region) error correspond to the "Data", divided by themselves, and depict the sensitivity to the theory calculations. Only calculations with the same input parameters agree with the "Data" [3].

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